LATE SILURIAN TO EARLY DEVONIAN STRATIGRAPHY OF THE YEA-MOLESWORTH DISTRICT, VICTORIA

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Abstract

Nearly 16,000 ft of early Devonian and possibly latest Silurian siltstones, claystones, and fine to medium sandstones and granule conglomerates occur in the Yea-Molesworth district. The sequence can be divided into three basic units separated by two prominent plant-graptolite horizons closely associated with developments of granule and pebble conglomerates; these horizons vary from 8,000 to between 9,000 and 10,000 ft apart stratigraphically. The higher of these horizons containing *Monograptus* n. sp. cf. *praehercynicus* is shown to be of mid-Lower Devonian age and equivalent to the Flowerdale Member of the Humevale Formation previously discriminated to the SW. of the area. The known flora and fauna of the lower plant-graptolite horizon is not diagnostic with regard to the Silurian-Devonian boundary. The oldest rocks of the district are exposed in the core of a major anticline passing through Yea township.

Introduction

In 1929 a party from the Victorian Mines Department searched the Yea-Alexandra district for the remains of land plants in association with Upper Silurian graptolites. The plant remains were described by Lang and Cookson (1935); graptolites found in association with this flora were identified by Ellis (1935) as varieties of *Monograptus uncinatus*, thus dating the flora as Lower Ludlow in age. Subsequently, Harris and Thomas (1942) described the various localities in the Yea-Alexandra district and noted the strong palaeontologic and stratigraphic similarity to the rocks along the Yarra Track. The discovery of plants and graptolites in investigations to the W. by Schleiger (1964), and subsequently by Williams (1964) to the SW., indicated that some clarification of the relationships of the various localities in the Yea-Molesworth district was desirable, particularly in view of the forthcoming 'Geology of Victoria' and renewed interest in latest Silurian to early Devonian graptolites and land plants.

The area studied (Fig. 1) centres on the township of Yea, extending for nearly 13 miles across the strike of the Siluro-Devonian sediments from an area recently investigated by Williams (1964) on the W. to an area being investigated by Garrett on the E.

Structural Geology

The rocks of the area form a series of anticlines and synclines trending N.50° W. in the W. part of the area, swinging round to N.70° W. in the E. parts. Several fold belts can be recognized, the two most important of which are:

(a) An anticlinal belt passing through the township of Yea exposing the oldest sediments of the area in its core (Unit C); this belt plunges at an angle of 15° SE.

(b) A synclinal belt runs from Killingworth (locations 57 and 58) to the railway at Cheviot. The rocks in the core of this belt have been subject to intensive folding, faulting, and differential movements resulting in incompatible drag-folds in the siltstones.

Minor folds are generally restricted to rather narrow belts occurring commonly in the cores of major synclinal belts. Except along the railway line at Cheviot where the plunge is toward the NW., the plunge of minor folds is to the SE. at angles varying from 15° to 50°. In most instances the thickness of beds remains uniform across minor folds. Slickensided bedding planes are extremely common, the slicks showing the direction of movement between individual beds to have been normal to the fold axes. These features indicate concentric folding.

Drag folds occur in fine sandstones only in closely folded belts; in all cases these drag folds are incompatible, i.e. the axes of the drags do not parallel but are almost normal to the fold axes. The occurrence of the drag folds in closely folded synclinal belts, along with the evidence for concentric folding, suggests some genetic relationship.

Faulting is developed only to a minor extent in closely folded regions, e.g. at Cheviot. Reverse faults with throws of up to 20 ft and minor displacements of the order of 6 in. in the crests of anticlines occur, but no evidence for major faulting could be found.

There are two joint systems, one related to transverse shearing stress and the other to longitudinal compression. In many places a combination of joint systems and breakage along bedding planes results in splintering of the claystones into 'pencil shales'. At other localities the weathered cores between joints and bedding planes in claystones reflects the strain ellipsoids for those localities, their orientation indicating maximum compression transverse to the strike.

Stratigraphy

The sediments of the Yea-Molesworth area can be divided into three conformable units, here labelled A, B, and C (Fig. 2). The base of units B and C is marked by intraformational conglomerates; the tops of units A and B are marked by plant-graptolite horizons referred to below as the No. 1 and No. 2 plant-graptolite associations respectively. The higher or No. 2 plant-graptolite horizon is in effect the Flowerdale Member of Williams (1964), though graptolites were not recorded from it by him. I have refrained from using formal stratigraphic nomenclature on this occasion for the simple reason that the Yea-Molesworth district lies intermediate between the area recently described by Williams, with its series of new stratigraphic names, and the Eildon district to the E., where an older series of stratigraphic names embrace units of the same age (Thomas 1947, 1953). Further work in the intervening areas will doubtless clarify the nomenclature.

Unit A

A maximum thickness of 4,500 ft of rocks of this unit is exposed but its base is not seen. The lower 2,500 ft consists of sandstones with interbedded claystones, the sandstones being developed to thicknesses of up to 200 ft. The upper 2,000 ft consists of silty claystones with fine interbedded sandstones. In the last 200 ft below the No. 1 plant-graptolite horizon there is a predominance of medium sandstones with thicknesses of up to 50 ft. The No. 1 plant-graptolite horizon consists of claystones and silty claystones.

Unit B

This unit lies conformably on unit A, its thickness varying from 9-10,000 ft on the W. to 8,000 ft in the E.

In the Western Limb, overlying the plant horizon and subjected in part to isoclinal folding are approximately 4,000 ft of predominant claystones and silty

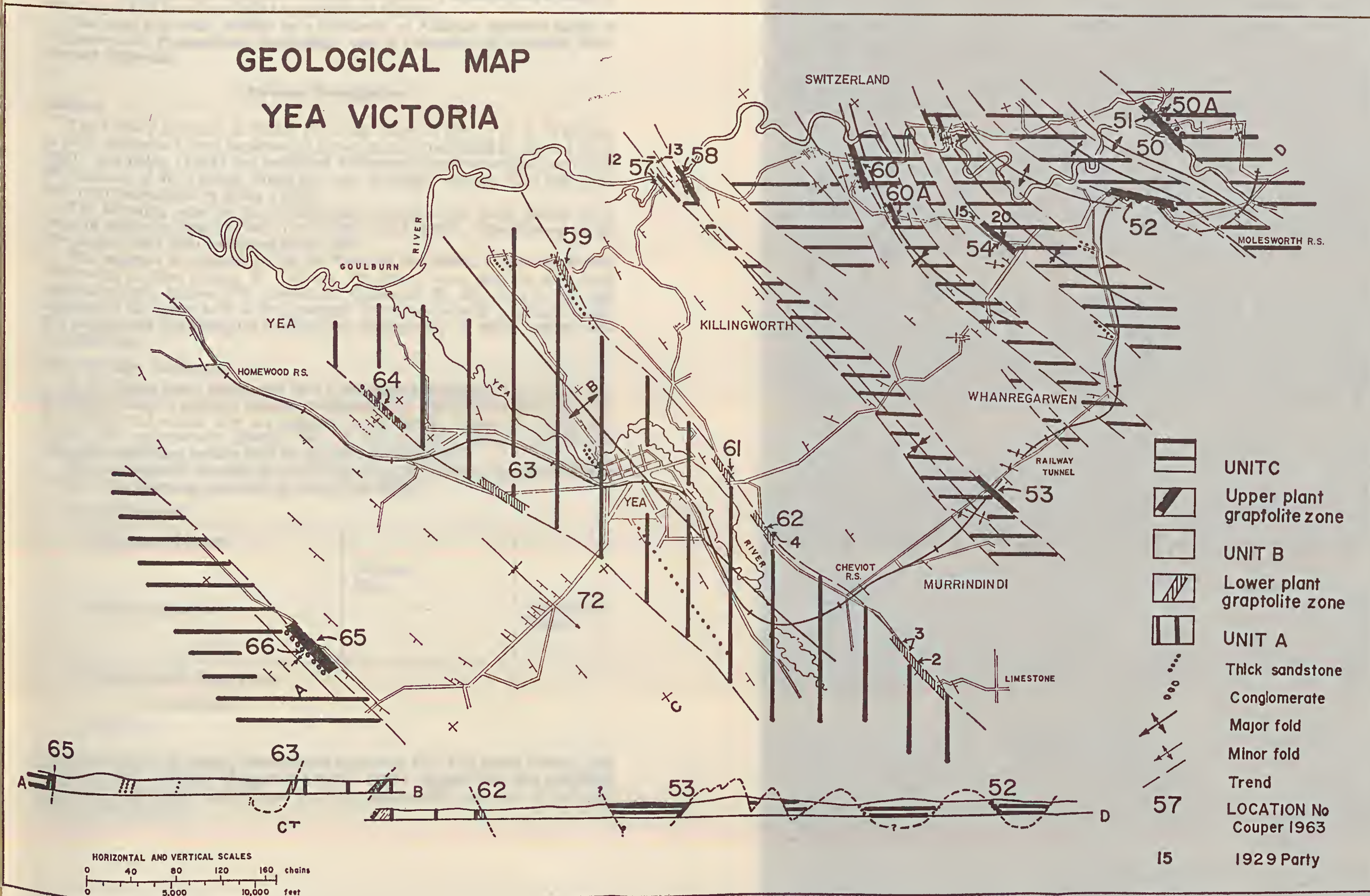
GEOLOGICAL MAP
YEA VICTORIA
SWITZERLAND
GOULBURN RIVER
YEA
HOMEWOOD R.S.
KILLINGWORTH
WHANREGARWEN
RAILWAY TUNNEL
CHEVIOT R.S.
MURRINDINDI
YEA RIVER
LIMESTONE
MOLESWORTH R.S.
UNIT C
Upper plant graptolite zone
UNIT B
Lower plant graptolite zone
UNIT A
Thick sandstone
Conglomerate
Major fold
Minor fold
Trend
57 LOCATION No Couper 1963
15 1929 Party
HORIZONTAL AND VERTICAL SCALES
0 40 80 120 160 chains
0 5,000 10,000 feet

Fig. 1

Several colleagues have supplied valuable comparative material and assisted in other ways. This is acknowledged specifically in the text.

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Previous Investigations

General

The Tertiary sequence at Pebble Point was recorded first by C. S. Wilkinson in 1865. Wilkinson's fossil localities are shown on maps published by Baker (1943, 1950), and Baker (1944) has published Wilkinson's excellent coastal section of the Tertiaries of W. Victoria. Fossil lists, etc., published between 1865 and 1923 have been summarized by Baker (1943).

The following notes on the stratigraphic succession are based mainly on a series of papers by Baker (1943, 1944, 1950, 1953, 1962), though many of his observations have been confirmed in the field.

The sequence is exposed on the W. flank of the broad, S.-pointing feature culminating in Cape Otway, W. Victoria. The lower, more resistant beds form spectacular cliffs; farther NW. toward the Gellibrand R., the relief is less and exposure of the higher beds is less complete. Reference is made to Baker's maps and photographs illustrating the location and physiography, to which nothing need be added here.

Stratigraphic Sequence

In the Otway Basin (McQueen 1961), the outcropping basal Tertiary overlies the Otway Group, a series of arkoses, mudstones, etc., which Baker (l.c.) refers to as 'Jurassic' but which now are assigned to the Lower Cretaceous (Dettmann 1963). The unconformity (Baker 1943, Pl. X) is sharp, being a clean-swept, somewhat undulating surface with no sign of a 'hard ground'.

The nomenclature currently in use for the overlying sequence is given by Baker (1953). The following tabulation is taken from Baker:

(covered interval)		
Princetown Member	DILWYN CLAY	WANGERRIP GROUP
Rivernook Member		
PEBBLE POINT FORMATION		
unconformity		
Mesozoic		

A compilation of Baker's observations is given in Fig. 1 of Baker (1953) and in Section 25 of Raggatt (Raggatt & Crespin 1955). Raggatt has also published observations by Reeves and Evans in 1949 (Section 26) and one of his own sections (Section 27).

The sequence dips at 4 or 5 degrees in a westerly direction. There is some faulting (Baker l.c.) but no evidence as yet that the sedimentary succession is not continuous.

The Pebble Point Formation is a series of fine grits, sands, and gritty or sandy clays. Though mainly ferruginous, it is carbonaceous in part, especially near the base, and it is glauconitic in part higher in the sequence. The shelly marine fauna (Baker 1943, Singleton 1943, Teichert 1943) is found in large blocks of limonitic or glauconitic conglomerates and grits at the foot of the cliffs. It comes mainly, or perhaps entirely, from the thin horizon in the upper part of the formation referred to by Baker as 'fossiliferous grit', and by Raggatt as 'lenticular, shelly fine conglomerate'. While this is the most obviously marine horizon in the formation, Baker has referred repeatedly to the unit as a whole as a 'littoral deposit'; and he has observed microscopic traces of marine fossils from several parts of the unit (Baker, pers. comm.). The thickness of the Pebble Point Formation is given as 50 ft by Baker, but as more than 100 ft by Reeves and Evans and by Raggatt.

The Dilwyn Clay is a sequence of dark, carbonaceous clays, sandy in places, and carrying copiapite. The branching markings 'resembling algal remains' discussed in Baker's earlier papers are perhaps due to burrowing organisms (Baker 1953); but generally the unit is poorly fossiliferous. As well as the Rivernook Member, there are interbedded in the Dilwyn Clay several glauconitic sandstone bands with marine shelly faunas. Two of these are known as the '*Turritella* Bed' and the '*Trochocyathus* Bed' (Baker 1950, Fig. 2). Mineralogically (summarized in Baker 1953) they are similar to the Pebble Point Formation, as is the carbonaceous sandy shale bed (Princetown Member) near the top of the sequence.

The Rivernook Member is interbedded in the Dilwyn Clay about half-way up the section. Baker has estimated that it is separated from the Pebble Point Formation by roughly 500 ft, but the interval probably is much less. The Member is a clay, variably consolidated, with quartz, biotite flakes, and glauconite pellets. It has patches of gypsum and also pyrite, the decomposition of which presumably gives the limonitic coating over much of the microfauna recorded. Baker (1950, Fig. 2) gives the thickness as 20 ft.

Faunas, Floras, Age

In 1941, Singleton could state (p. 11) that 'Paleocene to Middle Eocene horizons are as yet unknown in Australia . . .'. Almost immediately, however, this picture changed, as noted by Singleton himself (1943), due to the new researches carried out and instigated by Baker. While corals, molluscs, shark teeth, etc., had been known since the time of Wilkinson, new studies indicated that the faunas, particularly from the Pebble Point Formation, were distinctly older than had been thought.

Singleton (1943) compared the molluscan assemblage (*Lahillia-Cucullaea* fauna; pelecypods and one scaphopod) from the Pebble Point Formation with the Wangaloan fauna of New Zealand in particular. Thus, he referred it tentatively to the Lower Eocene or possibly Paleocene. The Wangaloan now is omitted from the standard New Zealand stage sequence, the type section being correlated with the Turian or part of the lower Dannevirke series, i.e. Dano-Paleocene (Hornibrook & Harrington 1957). Nevertheless, Singleton's correlation is not affected by this, and it remained the firmest basis for dating the beds for several years.

The two nautiloids from the Pebble Point Formation, described by Teichert (1943, 1947) as *Aturoidea distans* Teichert and *Eutrephoceras victorianum* (Teichert), indicated an Eocene age. The presence of *Aturoidea distans*, together with *Lahillia, Cucullaea*, etc., in the Bahgallah Formation of W. Victoria (Kenley 1951, 1954) is good evidence for correlating this unit with the lithologically closely similar Pebble Point Formation.

Glaessner and Parr (Appendix, Baker 1943) found about 28 species of Foraminifera in the Pebble Point Formation. Their species list gives a good idea of the Pebble Point fauna (as it is known at present) but, at that time, the species known did not have the biostratigraphic significance which they have now. Glaessner and Parr accordingly restricted their conclusions to suggesting an Eocene age, not disagreeing with the molluscan evidence.

Glaessner and Parr found no Foraminifera in the clay beds (the Dilwyn Clay). Subsequently, Parr discovered a fauna in the Rivernook Member (Baker 1944, 1953) which, he believed, was similar to the fauna from the Pebble Point Formation. Parr's assemblages, however, show several of the differences listed in the present paper, and his unpublished notes show that he had recognized them.

Apart from *Cyclammina* in the Princetown Member (Baker 1953), the remaining fossils recorded from the Wangerrip Group have been listed by Baker (1950, p. 27). And as Baker (1953, p. 132) has expressed it, 'the sum total of this evidence [stratigraphy, minerals, fossils] is interpreted to indicate that all of the Older Tertiary deposits south-east of the mouth of the Gellibrand River belong to one Group that is probably virtually much the same age throughout, namely, Lower Eocene to Paleocene, the age assigned recently . . . to only the lower beds (Pebble Point Formation) in the Wangerrip Group'.

In a brief review of these studies with regard to the problem of the 'Anglesean Stage', Raggatt & Crespin (1955) state more definitely ('. . . there seems little doubt . . .') that the Pebble Point Formation is Paleocene, rather than Paleocene to Lower Eocene in age. No evidence is given for improving upon the more tentative conclusions of Baker, etc. Raggatt and Crespin list 6 species of Foraminifera from the lower Dilwyn Clay, but none of these forms has much significance.

Nothing new on faunas or age has been published since. Glaessner (1959, Table 1) placed the Pebble Point Formation in the Paleocene on the evidence considered here. Cookson and Eisenack (1961; see also here references to other work by Cookson) accepted Baker's (1953) conclusions for the purposes of correlation.

Harris (in press) has studied in detail the spores and pollen of the Wangerrip Group. He has been able to zone the sequence as follows: (1) *Triorites edwardsii* Assemblage Zone (Pebble Point Formation and basal Dilwyn Clay); (2) *Triorites edwardsii—Duplopollis orthoteichus* Concurrent Range Zone (middle part of Dilwyn Clay, including Rivernook Member); (3) *Duplopollis orthoteichus* Assemblage Zone (upper part of Dilwyn Clay, including Princetown Member). By confirming, palynologically, the view (Baker 1953) that the upper part of the Dilwyn Clay was deposited continuously, and by accepting the present writer's conclusions (below) that the Rivernook Member is Middle to Upper Paleocene in age, Harris has suggested convincingly that the entire Wangerrip Group as exposed, including the Princetown Member, is Paleocene.

The Foraminiferal Faunas

It has been pointed out already that recovery of specimens from the Pebble Point Formation in particular was usually very difficult. Therefore, in compiling the faunal list (Table 1), all specimens recognized, from the diverse sources mentioned above, were counted. Inevitably, since standard methods of quantitative analysis were impracticable, the figures (see notes on each species) and also the percentages given below, are not reliable in a strictly statistical sense. And there are some forms which have been lumped together as 'species groups', and others where the material was too poor or too sparse to be determined.

Nevertheless, sufficient specimens are available to make these results meaningful in a broad way. The diversity of the Victorian Paleocene faunas has been established even though many species are represented by one or two specimens only. A total of about 120 species is of the same order as the faunas from the Paleocene of Sweden (Brotzen 1948) or from the English Thanetian (Haynes 1958) which are richer in specimens.

There is nothing intrinsic in the assemblages to indicate that the fauna of the Pebble Point Formation is heterogenous. Probably most specimens came from the shelly horizon or lenses in the upper part. Similarly, the Rivernook fauna is handled as a single unit. In this case, Parr's assemblages show some differences from those collected by the writer (which vary among themselves for unexplained though probably preservational reasons). This is hardly surprising, since the Member is 20 ft thick and intermittently exposed. The differences are not important. Doubtless the clearcut distinctions between the Pebble Point Formation and Rivernook Member faunas will become somewhat less clearcut as more exposures from the intervening sequence are examined in detail.

Composition of Faunas

Total number of species recorded	120
Total in Pebble Point Formation	85
Total in Rivernook Member	82
Species in common	47
Planktonic component (specimens)—	
Pebble Point Formation	3%
Rivernook Member	37%
Family Cibicididae (equals Gavelinellidae plus Cibicididae of Reiss 1963); proportion of benthos (specimens)—	
Pebble Point Formation	51%
Rivernook Member	53%

For details, see Table 1.

Comparison and Contrast

The two faunas have rather less in common than Parr concluded (see Baker 1944, 1953). Slightly more than one-third of the total number of species are common to both. The most apparent difference is the great increase in specimens of planktonic species in the Rivernook Member. About the same number of benthonic specimens (2500-2700) is available from each fauna; thus, the influx of planktonics is real and not an accident of sampling.

Table 1

List of Species from Pebble Point Formation and Rivernook Member of Dilwyn Clay

Specimens counted from all material available. Therefore, conventional categories upgraded as follows: R, rare, 1-10; F, frequent, 11-20; C, common, 21-50; A, abundant, more than 50; *, many fragments present. For accurate counts, see notes on species. Occurrences in King's Park Shale (+) based on Parr Collection, Dept Geology, University of Western Australia. Occurrences in the Paleocene outside Australia (+) based on the literature and on comparative material.